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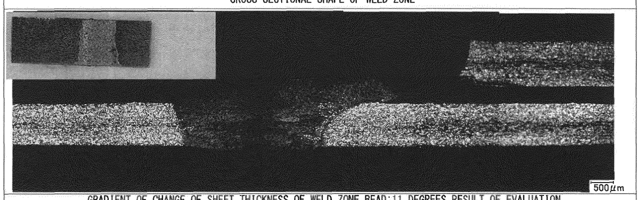
(54) STAINLESS STEEL SHEET FOR EXHAUST SYSTEM COMPONENT HAVING EXCELLENT INTERMITTENT OXIDATION CHARACTERISTICS, AND EXHAUST SYSTEM COMPONENT

(57) A stainless steel sheet free of surface flaws, having an enhanced high temperature strength and corrosion resistance, not becoming brittle at a high temperature, and further exhibiting a high oxidation resistance enabling it to be suitably used as an inside pipe of a double pipe of an exhaust manifold, a turbocharger part, and other automobile exhaust system parts, which stainless steel sheet has a predetermined composition of chemical components and satisfies Cr+20Mo≥24.0%, and Si+20C+15N≥5.8%. Further, an automobile exhaust system part, excellent in both the oxidation resistances of the base material and weld zone using the above stainless steel sheet, having a gradient of change of sheet thickness between the weld metal and the base material of the above stainless steel sheet of 15 degrees or less.

FIG. 2

CROSS-SECTIONAL SHAPE OF WELD ZONE



GRADIENT OF CHANGE OF SHEET THICKNESS OF WELD ZONE BEAD:11 DEGREES, RESULT OF EVALUATION OF OXIDATION RESISTANCE:PASSING (REDUCTION OF SHEET THICKNESS OF HEAT AFFECTED ZONE:0.3mm)

GRADIENT OF CHANGE OF SHEET THICKNESS OF WELD ZONE BEAD:25 DEGREES, RESULT OF EVALUATION OF OXIDATION RESISTANCE:FAILING (REDUCTION OF SHEET THICKNESS OF HEAT AFFECTED ZONE:1.2mm OR MORE)

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Description

Technical Field

[0001] The present invention relates to a heat resistant stainless steel sheet excellent in intermittent oxidation characteristic and to an exhaust system part. The exhaust system part of the present invention is particularly preferable as a part used in an environment where it is repeatedly heated to a high temperature of 1000°C or more such as an exhaust manifold or turbocharger part of an automobile engine.

Background Art

[0002] Materials used for the exhaust system parts of automobiles require high thermal fatigue characteristics and are being demanded to be excellent in oxidation resistance and resistance to peeling of oxide scale at a high temperature since the parts are exposed to a high temperature exhaust gas atmosphere and are repeatedly heated and cooled. For example, in the past, SUH409, SUS429, SUS430J1L, SUS436L, SUS444, and other ferritic stainless steels have been used for exhaust manifolds, front pipes, and converter shells. This is because these steels have 700 to 900°C or so heat resistance and are relatively inexpensive. Among these, high alloy stainless steels have been used in accordance with the required heat resistance temperature.

[0003] Further, exhaust manifolds are also made using austenitic stainless steel SUS310S (25Cr-20Ni-0.5Si), or SUS302B (18Cr-8Ni-2Si), XM15J1 (20Cr-12Ni-3Si), DIN1.4828 (19Cr-11Ni-2Si), etc. These are more expensive compared with ferritic stainless steel. The types of steels are selected according to their availability in each region, shaping technology, and other environmental factors.

[0004] However, there was the problem that at a temperature over 900°C, with ferritic stainless steel, the strength is insufficient, while with austenitic stainless steel, there is a problem with thermal fatigue and scale peeling and therefore neither can be used.

[0005] Further, for exhaust manifolds and turbocharger parts, heat resisting cast steel and stainless cast steel such as shown in PLT 1 are also being used, but there is a high need for reducing the weight of auto parts. Efforts are being made to replace cast parts with parts made by press forming sheet materials.

[0006] Recently, the need for improving the fuel economy of automobiles has become extremely high. As one means for improving fuel economy, engines are being made smaller in size and higher in output. Exhaust gas temperatures have tended to rise as a result. PLT 2 discloses a material comprised of the ferritic stainless steel SUS444 to which Mo or Nb, Cu, W, etc. is further added to raise the high temperature strength and secure heat resistance at 950°C. However, there was a problem with the workability and manufacturability at room temperature. There was also a problem when working the steel into complicated shapes such as an exhaust manifold. Further, there was a problem with sheet breakage etc. when producing sheet.

[0007] On the other hand, when applying austenitic stainless steel, there is no problem in terms of strength, but there is a large problem with thermal fatigue. PLT 3 discloses to reduce the Mo content as much as possible, add a fine amount of V, and control the crystal grain size and surface roughness of hot rolled sheet to thereby obtain hot rolled steel sheet excellent in heat resistance in a 900°C or more repeated heating and cooling environment. However, there were the problems that it was difficult to obtain the sheet thickness required for automobile exhaust system parts by hot rolling and the required precision of sheet thickness could not be obtained.

[0008] Further, to improve the heat resistance through the structure of an exhaust system part, the practice has been to make the exhaust manifold or turbocharger part a double pipe structure. Specifically, austenitic stainless steel is used at the inside and ferritic stainless steel is used at the outside to ease the constraints on the inside austenitic stainless steel member and reduce the thermal strain. By preventing the outside ferritic stainless steel from directly contacting the high temperature exhaust gas due to this, it becomes possible to lower the temperature. Such a double structure part is expensive but is frequently used in an exhaust manifold where the exhaust gas temperature is 1000°C or less. Further, it is sometimes used even at a 900°C or less exhaust gas temperature for suppressing oxidation at the outer surface of the exhaust manifold and enhancing the aesthetic appearance. However, these approaches lose effect and a sufficient heat resistance cannot be obtained if the exhaust gas temperature rises to a temperature over 1000°C. For this reason, an exhaust system part having a heat resistance in a 1000°C or more exhaust gas environment has been sought.

Citation List

Patent Literature

[0009]

PLT 1: Japanese Patent Publication No. 2006-118048A
PLT 2: Japanese Patent Publication No. 9-87809A
PLT 3: Japanese Patent Publication No. 2012-207252A

Summary of Invention

Technical Problem

[0010] The present invention has as its object to provide a stainless steel sheet free of surface flaws, having an enhanced high temperature strength and corrosion resistance, not becoming brittle at a high temperature, and further exhibiting a high oxidation resistance enabling it to be suitably used as an inside pipe of a double pipe of an exhaust manifold, a turbocharger part (including case of double pipe structure), and other automobile exhaust system parts. Further, the present invention has as its object to provide an automobile exhaust system part excellent in both the oxidation resistances of the base material and weld zone using the above stainless steel sheet.

Solution to Problem

[0011] The inventors first reevaluated the chemical composition to solve the above problems. As austenitic stainless steel with an excellent oxidation resistance, stainless steel raised in Si content or stainless steel having an REM added, such as the above-mentioned SUS302B, XM15J1, and DIN1.4828, is generally used.

[0012] The inventors engaged in intermittent oxidation tests in an atmospheric gas simulating an automobile exhaust gas environment so as to confirm if the above-mentioned austenitic stainless steels can withstand a 1050°C environment, but with each steel type, there was a remarkable reduction in weight due to the oxidation. It was judged there was no oxidation resistance at 1050°C.

[0013] Therefore, the inventors engaged in various studies to clarify the composition of a material able to withstand a 1050°C environment.

[0014] As a result, they discovered that when controlling the amounts of Cr, Mo, and Si to suitable amounts while adding predetermined amounts of Ni, C, and N to stabilize the austenite matrix, a stainless steel sheet having an oxidation resistance enabling it to withstand 1050°C can be obtained by the method of securing the amount of carbonitrides inhibiting grain growth of the austenite phase and controlling the form of precipitation so as to form scale with a high protective ability even in an intermittent oxidation environment.

[0015] Specifically, by controlling the amounts of Cr and Mo to predetermined ranges, an oxide scale is formed mainly comprised of Cr_2O_3 resistant to diffusion of oxygen ions and diffusion of metal ions in the scale.

[0016] An inside oxide layer is formed so that the scale does not peel off due to thermal expansion and contraction of the base material at the time of heating and cooling. The "inside oxide layer" indicates the Si oxides formed at the austenite grain boundary. If scale mainly comprised of Cr_2O_3 with a high protective ability cannot be formed at the surface, this grain boundary oxidation becomes shallower and prevention of scale peeling is difficult. Further, if austenite grains grow, grain boundary oxidation is inhibited due to movement of the grain boundaries, so the oxidation resistance is impaired. Therefore, the precipitates are made to disperse so as to inhibit grain growth.

[0017] FIG. 1 shows the results of investigation of the effects which Cr and Mo and Si, C, and N have on the oxidation resistance in intermittent oxidation. The test method is as follows:

[0018] Each of the various compositions of austenitic stainless steel was melted in a laboratory, heated at 1250°C for 1 hour, and hot rolled to a sheet thickness of 3 mm, then the hot rolled sheet was annealed at 1100°C for 20 seconds, immediately water cooled, shot blasted, then descaled by sulfuric acid and nitric hydrofluoric acid.

[0019] After that, the sheet was cold rolled to a thickness of 1.2 mm. Further, it was annealed at 1100°C for 20 seconds, then water cooled. The scale was modified by salt, then was pickled.

[0020] The surface was polished by SiC paper #600, then the sheet was repeatedly heated and cooled in an automobile exhaust gas atmosphere between 1050°C and 200°C in an intermittent oxidation test. A sheet with a reduction in sheet thickness of over 0.4 mm at the 2000th cycle in the number of repeated cycles was evaluated as "failing", while one with a reduction of 0.4 mm or less was evaluated as "passing". If summarizing the test results, as shown in FIG. 1, it is clear that to inhibit surface oxidation, Cr and Mo has the effect by the coefficients shown in the figure, while to inhibit peeling of scale, Si, C, and N has the effect by the coefficients shown in the figure. Note that, in FIG. 1, the white dots indicate "passing" while the black dots indicate "failing".

[0021] Due to these measures relating to the components, in a sheet, an oxidation resistance enabling the sheet to withstand 1050°C is obtained. However, when it comes to a welded structure such as an exhaust system part, that alone is not sufficient. FIG. 2 shows the cross-sectional shape of a lap fillet welded sample and the reduction in thickness after an oxidation test. This sample was used for an intermittent oxidation test, whereupon the oxidation became remarkable at the weld heat affected zone. As a result of the larger reduction of the sheet thickness, cases were seen in which the sample ended up separating (top left part of bottom photo of FIG. 2). For this reason, it is learned that the weld heat affected zone governs the lifetime of the exhaust system part. The state by which the weld heat affected zone selectively oxidizes was investigated, whereupon it was learned that at this part, scale mainly comprised of Cr_2O_3 is not uniformly formed at the surface and grain boundary oxidation does not occur much either.

[0022] Therefore, the compositions of the weld heat affected zone and base material were investigated, whereupon no difference could be recognized, so the difference in oxidation behavior of the base material and weld heat affected zone is believed to be the effect of strain due to thermal expansion and contraction. That is, due to the sheet thickness of the weld metal and base material, a temperature difference occurs between the weld metal and base material at the time of heating and cooling. Due to the thermal expansion and contraction stress resulting from the temperature difference, it is believed that scale easily peels off at the weld heat affected zone at the boundary.

[0023] The gradient (toe angle) of the change of sheet thickness at the weld zone of the sample was measured, whereupon it was learned that in a sample with a small oxidation, the toe angle was a small one of about 10 degrees, while in a sample with inferior oxidation resistance, the toe angle was a large 20 degrees. Note that, in the present invention, the "gradient of change of sheet thickness (toe angle)" indicates what is shown by the angle of (180-X) when, in observation of one surface of the weld zone, defining the angle by which the surface of the base material and the surface tangent of the weld bead (weld metal) intersect as X degrees. The toe angle is usually shown in a range of 0 to 90 degrees. In general, a weld bead has a plurality of toes, so there are a plurality of angles of toes, but the toe angle in the present invention is defined as the largest angle in a cross-sectional field of view. The toe angle being large means the gradient of change of the sheet thickness due to the bulging of the weld bead surface (buildup) being sharp.

[0024] Therefore, the following test was used to investigate the effect of the difference in sheet thickness between the weld metal and base material on the oxidation resistance, whereupon it was learned that if a specific difference of sheet thickness or more, scale peeling occurs at the weld heat affected zone and the oxidation resistance falls.

[0025] Specifically, 24Cr-12Ni-0.1C-0.02N-2.0Si-1Mn-0.5Mo-0.05Al-0.05Vsteel was melted in a laboratory, heated at 1250°C for 1 hour, and hot rolled to a sheet thickness of 3 mm, then the hot rolled sheet was annealed at 1100°C for 20 seconds, immediately water cooled, shot blasted, then descaled by sulfuric acid and nitric hydrofluoric acid. After that, the steel was cold rolled to a sheet thickness of 1.2 mm.

[0026] Further, the sheet was annealed at 1100°C for 20 seconds, then was water cooled. The scale was modified by salt, then immersed in a mixed acid of nitric acid and hydrofluoric acid to pickle it. The sheet was lap fillet welded by Tig welding. The welding was performed under conditions giving a back bead. For the weld wire, SUS310S was used. By changing the weld input heat and weld speed, the weld bead shape was changed and the gradient of the change of sheet thickness was changed.

[0027] The weld wire was placed at the center of the test piece to prepare an oxidation test piece, then this was heated and cooled between 200°C and 1050°C under an automobile exhaust gas environment in an intermittent oxidation test for 2000 cycles. The reduction in sheet thickness of the weld heat affected zone was measured. A reduction in sheet thickness of 0.4 mm or less was deemed the "passing" level. As a result, it was learned that even if there is a difference in sheet thickness between the weld metal and base material, by making the gradient of change of sheet thickness 15 degrees or less, it becomes possible to mitigate the peeling of scale of the weld heat affected zone.

[0028] This effect was also investigated for butt welding in addition to lap fillet welding, but in each case, it was learned that by making the gradient of the change in sheet thickness 15 degrees or less, it was possible to greatly mitigate the oxidation of the weld heat affected zone. Furthermore, by reducing the gradient of change of sheet thickness, oxidation of the weld heat affected zone is mitigated more. If the gradient of the change of sheet thickness is eliminated, an oxidation resistance the same as the base material is obtained, but it is learned that the effect of improvement of the oxidation resistance at over 15 degrees is small. Note that, in the present invention, the type of the welding method is not limited, but in particular good results are obtained in the case of arc welding. In other welding methods as well, similar effects are obtained based on the technical mechanism disclosed by the present invention.

[0029] As explained above, it was learned that by optimizing the design of components in the base material and controlling the shape of the weld metal, it is possible to give the exhaust system part a durability enabling it to withstand 1050°C.

[0030] The present invention was made based on the above findings and has as its gist the following:

(1) A stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic comprising, by mass%, C: 0.05 to 0.15%, Si: 1.0% to 4.0%, Mn: 0.5 to 3.5%, P: 0.010 to 0.040%, S: 0.0001 to 0.010%, Cr: 20 to 30%, Ni: 8 to 25%, Mo: 0.01 to 1.5%, Al: 0.001 to 0.10%, and N: 0.13 to 0.50%, having a balance of Fe and unavoidable impurities, and having contents of Cr, Mo, Si, C, and N satisfying $Cr+20Mo \geq 24.0\%$ and $Si+20C+15N \geq 5.8\%$.

(2) The stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic according to (1), further comprising, by mass%, one or more of
Cu: 0.1 to 3.0%, V: 0.03 to 0.5%, Ti: 0.001 to 0.3%, Nb: 0.001 to 0.3%, B: 0.0001 to 0.0050%, and Ca: 0.001 to 0.010%.

(3) The stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic according to (1) or (2), further comprising, by mass%, one or more of W: 0.01 to 3.00%, Zr: 0.05 to 0.30%, Sn: 0.01 to 0.10%, Co: 0.01 to 0.30%, and Mg: 0.0002% to 0.010%.

(4) An exhaust system part having a welded structure using a stainless steel sheet according to any one of (1) to (3) as a base material and having a gradient of change of sheet thickness at a weld zone of 15 degrees or less.

Advantageous Effects of Invention

[0031] According to the present invention, it is possible to raise the oxidation resistance of a stainless steel sheet for exhaust system part use and of an exhaust system part. Further, the steel sheet seldom exhibits surface flaws, so it is possible to eliminate or streamline the surface grinding process (CG) at the time of sheet production. Due to the raising of the oxidation resistance, it becomes possible to make the exhaust system part thinner in sheet thickness. Due to the lightening of weight of the part, the effect of improvement of the fuel economy of the automobile is also obtained.

Brief Description of Drawings

[0032]

[FIG. 1] FIG. 1 is a graph showing the effects of components on the intermittent oxidation resistance of sheet at 1050°C.

[FIG. 2] FIG. 2 shows the shape of change of sheet thickness at a cross-section of the weld metal after lap fillet welding. The top section shows the case of a gradient of change of sheet thickness at the weld zone of 11 degrees while the bottom section shows the case of the same gradient of 25 degrees.

[FIG. 3] FIG. 3 is a graph showing the effects the gradient of the change of sheet thickness has on the oxidation resistance (reduction of sheet thickness) at 1050°C.

Description of Embodiments

[0033] Below, embodiments of the present invention will be explained. First, the reasons for limiting the steel composition of the stainless steel sheet in the embodiments will be explained. Note that, the symbols % of the compositions, unless otherwise indicated, mean mass%.

C: 0.05 to 0.15%

[0034] C is effective for raising the stability of the austenite structure and high temperature strength. Further, it forms carbides with Cr to inhibit the growth of austenite grains and suitably cause the growth of grain boundary oxides and improve the resistance to scale peeling. This effect is manifested with 0.05% or more of C, so the lower limit is made 0.05%. To stably inhibit grain growth, the content is preferably made 0.10% or more. If over 0.15%, the amount of Cr carbides increases, the chrome-poor layer at the grain boundaries increases, and even in high Cr austenitic stainless steel like in the present steel, the corrosion resistance required for an exhaust manifold member or turbocharger part of an automobile can no longer be maintained, so the upper limit is made 0.15% or less. From the viewpoint of the corrosion resistance, the content is preferably made 0.12% or less.

Si: 1.0% to 4.0%

[0035] Si is effective for oxidation resistance. In particular, it is effective for prevention of peeling of scale in intermittent oxidation. To form grain boundary oxides in an environment over 1000°C and inhibit peeling of scale at the surface, 1.0% or more of Si is necessary. To raise the oxidation resistance, the content is preferably made 2.0% or more. Further, Si is a ferrite stabilizing element. It increases the δ-ferrite amount at the solidified structure and causes the drop in hot workability in hot rolling, so the content is made 4.0% or less. In addition, Si promotes the formation of a sigma phase and leads to the concern over embrittlement at the time of high temperature, long term use, so the content is preferably made 3.5% or less.

Mn: 0.5 to 3.5%

[0036] Mn is an element added as a deoxidizer, enlarges the austenite single phase region, and contributes to stabilization of the structure. This effect clearly appears at 0.5% or more, so the content is made 0.5% or more. Further, by forming sulfides and reducing the amount of solute S in the steel, there is also the effect of improving the hot workability, so the content is preferably made 1.0% or more. On the other hand, excessive addition causes the corrosion resistance to fall, so the content is made 3.5% or less. Further, from the viewpoint of oxidation resistance, oxides of mainly Cr_2O_3 are preferable. Oxides of Mn are not preferable, so the content is preferably made 2.0% or less.

P: 0.010 to 0.040%

[0037] P is an element included as an impurity in the starting material of the molten pig iron or ferrochrome or other main starting materials. This is an element harmful to hot workability, so the content is made 0.040% or less. Note that the content is preferably 0.030% or less. Excessive reduction makes use of high purity starting materials essential and otherwise leads to an increase in costs, so the content is made 0.010% or more. Economically preferably it is desirably made 0.020% or more.

S: 0.0001 to 0.010%

[0038] S forms sulfide-based inclusions and causes deterioration of the general corrosion resistance (full surface corrosion or pitting) of steel materials, so the upper limit of the content is preferably lower and is made 0.010%. Further, the smaller the content of S, the better the corrosion resistance, but reduction of the S results in an increase in the desulfurization load and leads to an increase in the manufacturing cost, so the lower limit is preferably made 0.0001%. Note that, the content is preferably 0.001 to 0.008%.

Cr: 20 to 30%

[0039] Cr is an essential element in the present invention for securing the oxidation resistance and corrosion resistance. If less than 20%, these effects are not exhibited. On the other hand, if over 30%, the austenite single phase region is reduced and the hot workability at the time of manufacture is impaired, so the content is made 20 to 30%. Note that from the viewpoint of the oxidation resistance, the content is preferably made 24% or more. Further, if making the amount of Cr higher, the formation of a sigma phase causes embrittlement, so the content is preferably made 27% or less.

Ni: 8 to 25%

[0040] Ni is an element for stabilizing the austenite phase and, unlike Mn, an element effective for oxidation resistance. These effects are obtained with 8% or more, so the lower limit is made 8% or more. This also has an effect of inhibiting the formation of a sigma phase, so the content is preferably made 10% or more. On the other hand, excessive addition raises the solidification cracking sensitivity and lowers the hot workability as well, so the content is made 25% or less. Furthermore, to inhibit peeling of scale in intermittent oxidation, the content is preferably made 15% or less.

Mo: 0.01 to 1.5%

[0041] Mo, together with Si or Cr, is effective for forming a protective scale on the surface. This effect is obtained with 0.01%, so the lower limit is made 0.01% or more. Further, this is also an element effective for improvement of the corrosion resistance, so this is preferably added in 0.3% or more. On the other hand, this is also a ferrite-stabilizing element. If the amount of addition of Mo increases, it is necessary to increase the addition of Ni, so excessive addition is not preferable. Further, it sometimes promotes the formation of a sigma phase and causes embrittlement, so the content is made 1.5% or less. The effect of improvement of the corrosion resistance and oxidation resistance becomes substantially saturated at 0.8% or more, so the content is preferably made 0.8% or less.

Al: 0.001 to 0.10%

[0042] Al is an element added as a deoxidation element and improving the oxidation resistance. This effect is obtained at 0.001% or more, so the lower limit is made 0.001% or more. To raise the deoxidation efficiency, the content is preferably made 0.003% or more. On the other hand, excessive addition forms nitrides and causes a drop in the solute N amount whereby the high temperature strength falls, so the upper limit is made 0.10% or less. If considering the weldability as well, the content is preferably made 0.05% or less.

N: 0.13 to 0.50%

[0043] N is one of the elements extremely important in the present invention. Like C, it raises the high temperature strength. Also, it raises the austenite stability making reduction of Ni also possible. Further, the effect of reduction of the corrosion resistance due to sensitization is smaller than C, so a larger amount of addition than C is possible. To obtain high temperature strength able to withstand a high temperature environment, the content is made 0.13% or more. If considering the effect of reduction of Ni, the content is preferably made 0.25% or more. On the other hand, if added in a large amount, gas bubble-type flaws form at the time of solidification in the steelmaking process, so the upper limit is made 0.50% or less. In addition, the strength at ordinary temperature becomes too high, the load at the time of cold rolling becomes higher, and the productivity is impaired, so the content is preferably made 0.30% or less.

Cr+20Mo≥24.0% and Si+20C+15N≥5.8%

[0044] To obtain oxidation resistance at 1050°C, it is necessary to form an oxide scale with a high protective ability at the surface, while to suppress scale peeling at the time of intermittent oxidation, it is necessary to form grain boundary oxides by Si oxides in the austenite phase under the scale. For this reason, it is insufficient to just make the elements the above ranges of conditions. To form scale with a high protective ability, it is necessary to make the content Cr+20Mo of Cr and Mo 24% or more, while to inhibit the grain growth of austenite and cause grain boundary oxidation, it is necessary to make the content Si+20C+15N of Si, C, and N 5.8% or more. Cr+20Mo is more preferably 27.0% or more, still more preferably 30.0% or more. Si+20C+15N is more preferably 7.0% or more, still more preferably 8.5% or more.

Gradient of Change of Sheet Thickness Between Base Material and Weld Metal of 15 Degrees or Less

[0045] Most exhaust manifolds, turbochargers, and other exhaust system parts of automobiles have welded structures. If the difference in sheet thickness of the base material and weld metal is large, thermal strain is caused due to the temperature difference at the time of heating and cooling, the scale formed at the surface at the time of a high temperature easily peels off, and at the time of repeated heating, the surface is not protected, but is oxidized resulting in a reduction in sheet thickness. The smaller the gradient of change of sheet thickness between the base material and weld metal, the more the thermal strain is eased, so if the gradient of the change of sheet thickness becomes 15 degrees or less, the effect of improvement of the oxidation resistance becomes greater, so the gradient is made 15 degrees or less. To further improve the oxidation resistance, the gradient of change of sheet thickness is preferably reduced to 10 degrees or less.

[0046] Further, the stainless steel sheet of the present invention may further have added to it, in addition to the above elements, any one or more of Cu: 0.1 to 3.0%, V: 0.03 to 0.5%, Ti: 0.001 to 0.3%, Nb: 0.001 to 0.3%, B: 0.0001 to 0.0050%, and Ca: 0.001 to 0.010%.

Cu: 0.1 to 3.0%

[0047] Cu is a relative inexpensive element taking the place of Ni as an austenite-stabilizing element. Furthermore, it is effective for inhibiting the progression of crevice corrosion and pitting. For this reason, addition of 0.1% or more is preferable. However, in the production of austenitic stainless steel, Cu often enters from the scrap and other starting materials. About 0.2% is often included as an unavoidable impurity. However, if over 3.0%, the hot workability is lowered, so the content is made 3.0% or less.

V: 0.03 to 0.5%

[0048] V is present in the alloy starting materials of stainless steel as an unavoidable impurity and is difficult to remove in the refining process, so in general is included in 0.01 to 0.10% in range. Further, it forms fine carbonitrides and has a grain growth inhibiting effect, so is also an element which is deliberately added in accordance with need. This effect stably appears with 0.03% or more addition, so the lower limit is made 0.03%. Due to fluctuation of V, the crystal grain size changes, so this is not preferable, so to build in a certain range of crystal grain size, the content is preferably made 0.08% or more. On the other hand, if excessively added, it is liable to invite coarsening of the precipitate. As a result, the toughness after hardening ends up falling, so the upper limit is made 0.5%. Note that if considering the manufacturing cost or manufacturability, making the content 0.2% or less is preferable.

Ti: 0.001 to 0.3%

[0049] Ti, like Nb, is an element forming a carbonitride and inhibits sensitization or a drop in corrosion resistance due to precipitation of chrome carbonitrides in the stainless steel. However, surface flaws are easily caused by forming large sized steelmaking inclusions, so the upper limit is made 0.3% or less. If considering the improvement in the high temperature strength due to securing the solute C and N amounts, the content is preferably made 0.01% or less. Ti also need not be contained.

Nb: 0.001 to 0.3%

[0050] Nb is an element which forms carbonitrides and inhibits sensitization or a drop in corrosion resistance due to precipitation of chrome carbonitrides in the stainless steel. However, surface flaws are easily caused by forming large sized steelmaking inclusions, so the upper limit is made 0.3%. If considering the improvement in the high temperature strength due to securing the solute C and N amounts, the content is preferably made 0.01% or less. Nb also need not be contained.

B: 0.0001 to 0.0050%

[0051] B is an element effective for improvement of the hot workability. This effect appears at 0.0001% or more, so 0.0001% or more may be added. To improve the hot workability in a broader temperature region, 0.0005% or more is preferable. On the other hand, excessive addition becomes a cause of surface defects due to the drop in hot workability, so 0.0050% is made the upper limit. If considering the corrosion resistance, 0.0025% or less is preferable.

Ca: 0.001 to 0.010%

[0052] Ca is added as a desulfurizing element and has the effect of reduction of the S in the steel to improve the hot workability. In general, this is added as CaO into the slag at the time of melting and refining. Part of this dissolves in the steel as Ca. Further, it is also contained in steel as $CaO-SiO_2-Al_2O_3-MgO$ or other complex oxides. The effect of improvement of the hot workability is obtained from 0.001%, so the content is preferably made 0.001% or more. On the other hand, if contained in a large amount, relatively coarse aqueous inclusions CaS precipitate and the corrosion resistance is lowered, so the content is preferably made 0.010% or less.

[0053] Furthermore, in addition to the above elements, one or more of W: 0.01 to 3.00%, Zr: 0.05 to 0.30%, Sn: 0.01 to 0.10%, Co: 0.01 to 0.30%, and Mg: 0.0002 to 0.010% may be freely added.

W: 0.01 to 3.0%

[0054] W, like Cr and Mo, is an element for improving the corrosion resistance. Further, it also has the effect of raising the high temperature strength by solution strengthening. To obtain these effects, 0.01% or more is preferably added. On the other hand, it is an element promoting precipitation of a sigma phase. Age embrittlement causes a drop in the strength of the material, so 3.0% or less is preferable. Further, like Mo and Nb, this is an expensive element, so making it 1.5% or less is more preferable.

Zr: 0.05 to 0.30%

[0055] Zr, like Ti and Nb, is an element which forms carbonitrides and inhibits sensitization and a drop in corrosion resistance due to precipitation of chrome carbonitrides in stainless steel. However, surface flaws are easily caused by forming large sized steelmaking inclusions, so the upper limit is made 0.30% or less. If considering the improvement of high temperature strength due to securing solute C and N amounts, the content is preferably made 0.1% or less. Zr may also not be included.

Sn: 0.01 to 0.10%

[0056] Sn is an element effective for improvement of the corrosion resistance after hardening and is preferably added as needed in 0.02% or more. However, excessive addition promotes edge cracking at the time of hot rolling, so the content is preferably made 0.10% or less.

Co: 0.01 to 0.30%

[0057] Co is an element which easily is contained in austenitic stainless steel as an unavoidable impurity from the alloy starting materials. Further, it is an element effective for improving the high temperature strength, so addition of 0.01% or more is preferable. However, excessive addition becomes a cause of a drop in the hot workability and consequent formation of surface flaws, so the content is preferably made 0.30% or less.

Mg: 0.0002 to 0.010%

[0058] Mg, like Ca, is added as a desulfurizing element. In general, sometimes, MgO is contained in complex oxides in addition to an equivalent amount dissolving from the slag to inside the molten steel. Further, sometimes the MgO in the refractories leaches out into the molten steel. The desulfurization effect appears at 0.0002% or more, so preferably the lower limit is made 0.0002%. On the other hand, excessive addition causes aqueous inclusions MgS to coarsely precipitate and corrosion resistance to be reduced, so the content is preferably made 0.010% or less.

[0059] The remainder of the chemical composition consists of Fe and unavoidable impurities. The "unavoidable impurities" mean elements which are not deliberately included, but unavoidably enter from the starting materials or manufacturing environment etc. when industrially manufacturing stainless steel sheet having the chemical composition prescribed in the present invention.

[0060] The above-mentioned optionally added elements sometimes enter as unavoidable impurities without knowing the content, but there is no particular problem so long as the content is not more than the upper limit explained above. Further, elements other than those mentioned above can also be included in a range not detracting from the effects of the present invention.

[0061] By making the chemical composition the one explained above, it is possible to obtain a stainless steel sheet exhibiting a high oxidation resistance. Furthermore, by making it one having the above-mentioned weld shape, it is possible to obtain an exhaust system part excellent in oxidation resistances of both the base material and weld zone.

Examples

[0062] Below, examples will be used to explain the advantageous effects of the present invention, but the present invention is not limited to the conditions used in the following examples.

[0063] First, steel of each chemical composition shown in Table 1 was smelted and cast into a 200 mm thick slab. This slab was heated to 1200°C, then was roughly hot rolled and finally hot rolled to obtain a thickness 4 mm hot rolled steel sheet. To simulate being coiled at an 800°C temperature region, this was inserted into an 800°C heat treatment furnace and held for 1 hour, then air cooled. After this, the hot rolled sheet was annealed at 1100°C for 20 seconds, then was water cooled. After that, the sheet was shot blasted and pickled to remove the scale. The existence of any surface flaws was observed and evaluated by the naked eye and a X10 power loupe. A sheet where surface flaws can be confirmed by observation by either the naked eye or loupe was evaluated as "failing".

[0064] After that, the steel was cold rolled to a sheet thickness of 1.2 mm, then the cold rolled sheet was annealed at 1100°C for 20 seconds. The oxide film of the surface was modified by salt and pickled by nitric hydrofluoric acid to obtain a pickled skin.

[0065] The cold rolled sheet was measured for high temperature strength at 1000°C. One having a 0.2% yield strength of 30 MPa or more was evaluated as "passing". Further, the sheet was oxidized at 700°C for 300 hours, then the surface was polished to prepare a sheet. One which cracked was judged as failing in high temperature embrittlement.

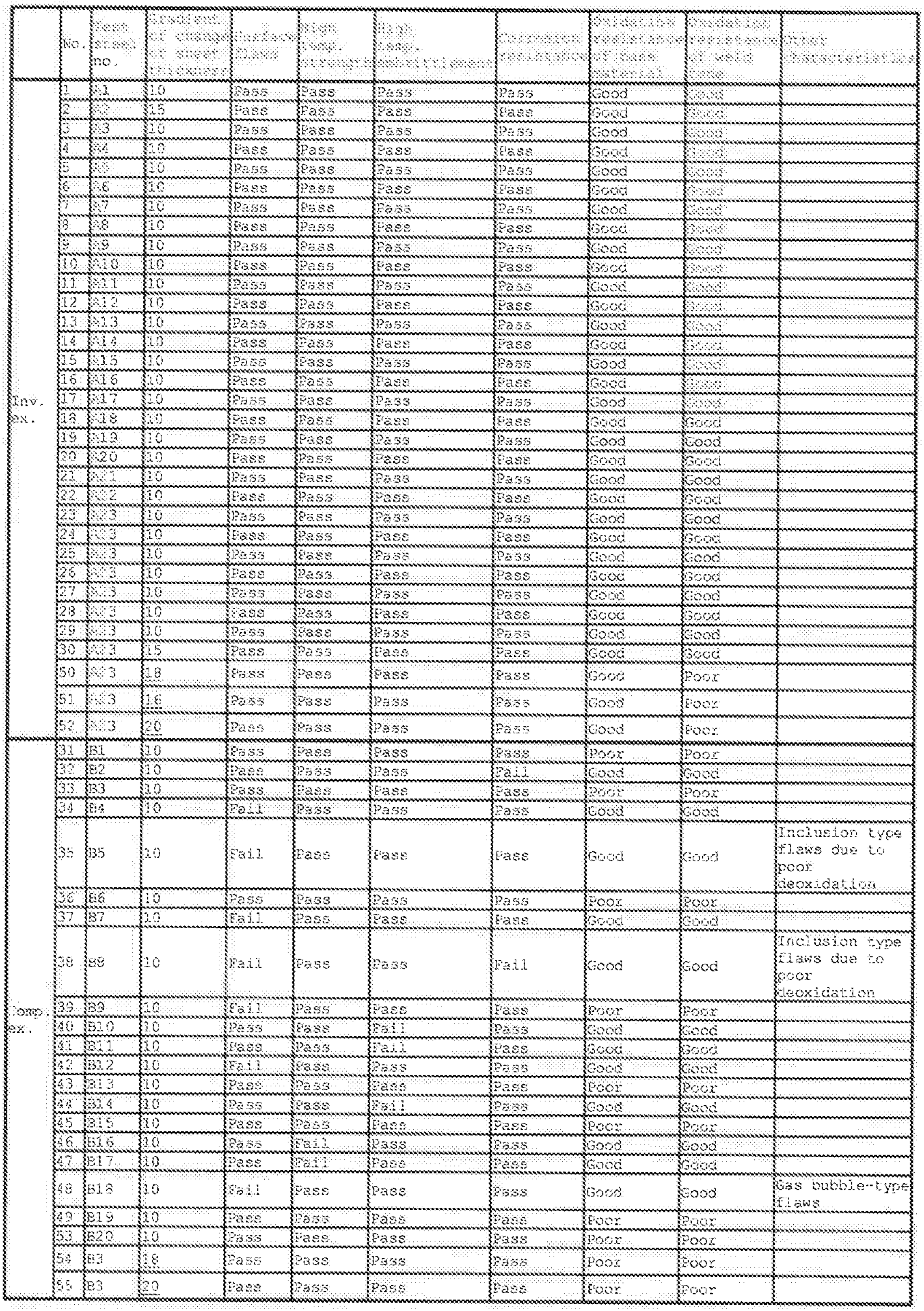
[0066] Further, the sheet was subjected to a JIS salt spray test. Samples which rusted were judged as failing in corrosion resistance. The oxidation resistance was evaluated by a test piece obtained by lap fillet welding one flat sheet and another as pickled. The oxidation test was performed in an atmosphere of H_2O of 5 to 10%, O_2 of 0.2 to 1.0%, and a balance of nitrogen. The atmospheric gas was made a composition simulating automobile exhaust gas with periodic changes. The test piece was heated to and held at 1050°C and then cooled to 200°C as one cycle. The test was performed for 2500 cycles. The appearance was recorded and the change in weight measured. The location most advanced in oxidation was recorded and the sheet thickness of that part was evaluated. 0.8 mm or more was evaluated as meaning a good oxidation resistance.

[0067] As comparative examples, samples with compositions and shapes of weld zones outside the present invention were similarly evaluated.

Table 1

	Test steel no.	C	Si	Mn	P	S	Cr	Ni	Mo	V	Al	N	Cr+20Mo	Si+20C +15N	Others (Ti, Nb, B, Ca, Sn, W, Zr, Co, and Mg)
Inv. ex. A	A1	0.08	2.00	1.51	0.025	0.004	25.3	10.5	0.2	0.10	0.01	0.25	29.3	7.35	
	A2	0.15	1.95	1.50	0.036	0.004	24.5	11.8	0.3	0.01	0.02	0.13	30.5	6.90	
	A3	0.09	1.00	1.00	0.024	0.005	24.1	11.0	0.2	0.09	0.01	0.20	28.1	5.80	
	A4	0.10	4.00	0.80	0.027	0.003	25.1	12.5	0.2	0.09	0.01	0.32	29.1	10.80	
	A5	0.11	1.90	0.50	0.026	0.006	25.2	10.8	0.5	0.08	0.01	0.35	35.2	9.35	0.3Ti
	A6	0.08	2.00	3.50	0.025	0.004	23.0	11.8	0.2	0.08	0.01	0.30	27.0	8.10	0.3Cu
	A7	0.09	1.90	0.60	0.040	0.002	22.0	12.5	0.3	0.08	0.01	0.30	28.0	8.20	0.3Nb
	A8	0.09	2.21	1.01	0.028	0.010	21.0	12.3	0.2	0.07	0.01	0.23	25.0	7.46	
	A9	0.10	2.50	1.40	0.024	0.003	20.0	12.1	0.2	0.08	0.01	0.20	24.0	7.50	0.010Ca
	A10	0.09	3.00	1.50	0.035	0.003	30.0	12.1	0.2	0.08	0.01	0.25	34.0	8.55	
	A11	0.11	1.90	1.30	0.025	0.015	26.1	8.0	0.1	0.08	0.01	0.24	28.1	7.70	0.0002B
	A12	0.09	2.10	1.20	0.021	0.004	25.1	15.0	0.2	0.09	0.01	0.27	29.1	7.95	
	A13	0.09	1.90	1.50	0.025	0.003	24.5	12.3	1.5	0.08	0.01	0.50	54.5	11.20	
	A14	0.08	2.20	1.21	0.025	0.002	24.7	10.5	0.3	0.08	0.01	0.25	30.7	7.55	0.005%B
	A15	0.10	1.90	0.80	0.026	0.005	24.0	11.4	0.2	0.08	0.1	0.25	28.0	7.65	0.02%Ti
	A16	0.05	2.50	1.10	0.028	0.005	23.8	11.6	0.2	0.05	0.001	0.25	27.8	7.25	1.0W
	A17	0.10	1.90	1.05	0.026	0.005	24.0	11.3	0.2	0.05	0.02	0.24	28.0	7.50	0.3Zr
	A18	0.09	2.10	1.20	0.024	0.005	23.5	11.9	0.2	0.08	0.01	0.24	27.5	7.50	0.1Sn
	A19	0.09	1.96	1.47	0.026	0.000	24.3	12.0	0.4	0.10	0.03	0.23	32.3	7.21	0.30Co
	A20	0.09	1.96	1.47	0.026	0.000	24.3	12.0	0.6	0.10	0.03	0.23	36.3	7.21	0.010Mg
	A21	0.09	1.96	1.47	0.026	0.000	24.3	12.0	0.2	0.10	0.03	0.23	28.3	7.21	0.2Zr +0.002B
	A22	0.09	1.96	1.47	0.026	0.000	24.3	12.0	1.0	0.10	0.03	0.23	44.3	7.21	0.2Nb +0.1Co
	A23	0.09	1.96	1.47	0.026	0.000	24.3	12.0	0.6	0.01	0.03	0.23	36.3	7.21	0.002B +0.02Nb
Comp. ex. B	B1	0.04	1.96	1.50	0.026	0.001	21.0	11.0	0.2	0.10	0.03	0.23	25.0	6.21	
	B2	0.16	1.90	1.20	0.026	0.001	22.0	10.0	0.5	0.05	0.05	0.30	32.0	9.60	
	B3	0.09	0.90	1.20	0.026	0.001	23.0	15.0	0.2	0.10	0.03	0.20	27.0	5.70	
	B4	0.08	4.10	1.30	0.026	0.001	25.0	14.0	0.2	0.10	0.05	0.23	29.0	9.15	
	B5	0.09	1.80	0.40	0.026	0.001	24.0	12.0	0.4	0.08	0.03	0.25	32.0	7.35	
	B6	0.10	1.96	3.60	0.026	0.001	25.0	12.0	0.3	0.09	0.05	0.24	31.0	7.56	
	B7	0.09	1.20	1.20	0.042	0.001	23.0	12.0	0.2	0.07	0.03	0.23	27.0	6.45	
	B8	0.11	1.70	1.47	0.026	0.012	25.0	12.0	0.4	0.08	0.000	0.23	33.0	7.35	
	B9	0.09	1.50	0.80	0.026	0.001	19.0	11.0	0.2	0.08	0.03	0.25	23.0	7.05	
	B10	0.12	1.80	0.70	0.026	0.001	31.0	25.0	0.4	0.12	0.05	0.24	39.0	7.80	
	B11	0.10	1.80	0.60	0.026	0.002	24.0	7.0	0.2	0.14	0.03	0.22	28.0	7.10	
	B12	0.11	1.90	0.50	0.026	0.001	26.0	26.0	0.3	0.10	0.10	0.21	32.0	7.25	
	B13	0.09	2.50	0.80	0.026	0.001	25.0	17.0	0.00	0.15	0.03	0.23	25.0	7.75	
	B14	0.09	2.20	0.90	0.026	0.001	24.0	12.0	1.6	0.16	0.10	0.26	56.0	7.90	
	B15	0.09	2.10	0.80	0.026	0.001	22.0	12.0	0.5	0.60	0.10	0.27	32.0	7.95	
	B16	0.10	2.00	0.80	0.026	0.001	23.0	13.0	0.2	0.12	0.12	0.23	27.0	7.45	
	B17	0.10	2.10	0.70	0.026	0.001	21.0	12.0	0.3	0.10	0.03	0.12	27.0	5.90	
	B18	0.10	2.10	0.90	0.026	0.001	25.0	11.0	0.5	0.12	0.03	0.52	35.0	11.90	
	B19	0.09	2.10	0.90	0.026	0.001	22.0	12.0	0.00	0.12	0.05	0.23	22.0	7.35	
	B20	0.08	1.00	1.10	0.026	0.002	22.0	13.0	0.2	0.10	0.12	0.20	26.0	5.60	

Table 2



	No.	Test steel no.	Gradient of change of sheet thickness	Surface flaws	High temp. strength	High temp. embrittlement	Corrosion resistance	Oxidation resistance of base material	Oxidation resistance of weld zone	Other characteristics
Inv. ex.	1	A1	10	Pass	Pass	Pass	Pass	Good	Good	
	2	A2	15	Pass	Pass	Pass	Pass	Good	Good	
	3	A3	10	Pass	Pass	Pass	Pass	Good	Good	
	4	A4	10	Pass	Pass	Pass	Pass	Good	Good	
	5	A5	10	Pass	Pass	Pass	Pass	Good	Good	
	6	A6	10	Pass	Pass	Pass	Pass	Good	Good	
	7	A7	10	Pass	Pass	Pass	Pass	Good	Good	
	8	A8	10	Pass	Pass	Pass	Pass	Good	Good	
	9	A9	10	Pass	Pass	Pass	Pass	Good	Good	
	10	A10	10	Pass	Pass	Pass	Pass	Good	Good	
	11	A11	10	Pass	Pass	Pass	Pass	Good	Good	
	12	A12	10	Pass	Pass	Pass	Pass	Good	Good	
	13	A13	10	Pass	Pass	Pass	Pass	Good	Good	
	14	A14	10	Pass	Pass	Pass	Pass	Good	Good	
	15	A15	10	Pass	Pass	Pass	Pass	Good	Good	
	16	A16	10	Pass	Pass	Pass	Pass	Good	Good	
	17	A17	10	Pass	Pass	Pass	Pass	Good	Good	
	18	A18	10	Pass	Pass	Pass	Pass	Good	Good	
	19	A19	10	Pass	Pass	Pass	Pass	Good	Good	
	20	A20	10	Pass	Pass	Pass	Pass	Good	Good	
	21	A21	10	Pass	Pass	Pass	Pass	Good	Good	
	22	A22	10	Pass	Pass	Pass	Pass	Good	Good	
	23	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	24	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	25	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	26	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	27	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	28	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	29	A23	10	Pass	Pass	Pass	Pass	Good	Good	
	30	A23	15	Pass	Pass	Pass	Pass	Good	Good	
	50	A23	18	Pass	Pass	Pass	Pass	Good	Poor	
	51	A23	16	Pass	Pass	Pass	Pass	Good	Poor	
	52	A23	20	Pass	Pass	Pass	Pass	Good	Poor	
Comp. ex.	31	B1	10	Pass	Pass	Pass	Pass	Poor	Poor	
	32	B2	10	Pass	Pass	Pass	Fail	Good	Good	
	33	B3	10	Pass	Pass	Pass	Pass	Poor	Poor	
	34	B4	10	Fail	Pass	Pass	Pass	Good	Good	
	35	B5	10	Fail	Pass	Pass	Pass	Good	Good	Inclusion type flaws due to poor deoxidation
	36	B6	10	Pass	Pass	Pass	Pass	Poor	Poor	
	37	B7	10	Fail	Pass	Pass	Pass	Good	Good	
	38	B8	10	Fail	Pass	Pass	Fail	Good	Good	Inclusion type flaws due to poor deoxidation
	39	B9	10	Fail	Pass	Pass	Pass	Poor	Poor	
	40	B10	10	Pass	Pass	Fail	Pass	Good	Good	
	41	B11	10	Pass	Pass	Fail	Pass	Good	Good	
	42	B12	10	Fail	Pass	Pass	Pass	Good	Good	
	43	B13	10	Pass	Pass	Pass	Pass	Poor	Poor	
	44	B14	10	Pass	Pass	Fail	Pass	Good	Good	
	45	B15	10	Pass	Pass	Pass	Pass	Poor	Poor	
	46	B16	10	Pass	Fail	Pass	Pass	Good	Good	
	47	B17	10	Pass	Fail	Pass	Pass	Good	Good	
	48	B18	10	Fail	Pass	Pass	Pass	Good	Good	Gas bubble-type flaws
	49	B19	10	Pass	Pass	Pass	Pass	Poor	Poor	
	53	B20	10	Pass	Pass	Pass	Pass	Poor	Poor	
	54	B3	18	Pass	Pass	Pass	Pass	Poor	Poor	
	55	B3	20	Pass	Pass	Pass	Pass	Poor	Poor	

[0068] As clear from Tables 1 and 2, in the invention examples having the chemical compositions and parameters of components prescribed in the present invention, the oxidation resistances of the base materials were excellent, the surface flaws, high temperature strengths, and high temperature embrittlements were evaluated as "passing", and the corrosion resistances were also excellent. In particular, No. 1 to No. 30 were controlled in weld bead shapes to the range of the present invention. As a result, not only the base materials, but also the weld zones were excellent in oxidation resistance. On the other hand, with chemical compositions outside the present invention, the oxidation resistances were poor and, also, the different characteristics of surface flaws, high temperature strengths, high temperature embrittlements, corrosion resistances, and oxidation resistances were hard to simultaneously achieve. The comparative examples failed in any of these characteristics. Due to this, it is learned that the comparative examples were inferior in characteristics to the invention examples.

[0069] Specifically, Test No. 31 was low in C, No. 33 was low in Si, No. 36 was high in Mn, No. 43 was low in Mo, No. 45 was high in V, Nos. 49 and 53 were low in Cr+20Mo or low in Si+20C+15N, so both the base materials and the weld zones were poor in oxidation resistance. No. 32 was high in C, so the corrosion resistance was poor.

[0070] No. 34 was high in Si, No. 35 was low in Mn, No. 37 was high in P, No. 42 was high in Ni, and No. 48 was high in N, so surface flaws formed and the results were poor. No. 38 was high in S and low in Al, so the result was poor in surface flaws and the corrosion resistance was poor. No. 39 was low in Cr and low in Cr+20Mo, so the result was poor in surface flaws and the base materials and weld zones were poor in oxidation resistance.

[0071] No. 40 was high in Cr, No. 41 was low in Ni, and No. 44 was high in Mo, so the results were poor in high temperature embrittlements. No. 46 was high in Al and No. 47 was low in N, so the high temperature strengths were poor.

[0072] Further, No. 49 did not contain Mo and, due to this as well, was low in Cr+20Mo, so the base material and weld zone were both poor in oxidation resistance. Nos. 50 to 52, 54, and 55 were large in gradients of change of sheet thickness at the weld zones, so the weld zones were poor in oxidation resistances.

[0073] Among these, Nos. 50 to 52 used A23 satisfying the requirements of the present invention as the test steels. For this reason, Nos. 50 to 52 were poor in only the oxidation resistances of the weld zones, but were satisfactory in the oxidation resistances of the base materials and other properties and performance, so can be applied to parts not requiring welding.

[0074] Further, No. 55 used B20 as the test steel and had a value of Cr+20C+15N of 5.60 or not satisfying the lower limit prescribed in the present invention, so was poor in oxidation resistances of the base material and weld zone.

[0075] Nos. 54 and 55 had large gradients of change of sheet thickness at the weld zones. Further, the test steel B3 was low in Si. Therefore, the oxidation resistances of not only the weld zones, but also the base materials were poor.

[0076] From these results, it was possible to confirm the above discoveries. Further, it was possible to back up the reasons for limiting the above steel compositions and configurations.

Industrial Applicability

[0077] The stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic and the exhaust system part of the present invention can be designed in components to raise the oxidation resistance and enable improvement of the oxidation resistance of the weld heat affected zone by control of the shape of the weld zone. Further, since there are few surface flaws, it is possible to eliminate or streamline the surface grinding process (CG) at the time of sheet production. Furthermore, by raising the oxidation resistance, it becomes possible to make the sheet thickness of the exhaust system part thinner. By lightening the weight of the part, the effect of improvement of the fuel economy of an automobile is also obtained, so there is large social significance and the present invention is large in industrial applicability.

Claims

1. A stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic comprising, by mass%,

    C: 0.05 to 0.15%,
    Si: 1.0% to 4.0%,
    Mn: 0.5 to 3.5%,
    P: 0.010 to 0.040%,
    S: 0.0001 to 0.010%,
    Cr: 20 to 30%,
    Ni: 8 to 25%,
    Mo: 0.01 to 1.5%,
    Al: 0.001 to 0.10%, and
    N: 0.13 to 0.50%,
    having a balance of Fe and unavoidable impurities, and
    having contents of Cr, Mo, Si, C, and N satisfying $Cr+20Mo\geq 24.0\%$ and
    $Si+20C+15N\geq 5.8\%$.

2. The stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic according to claim 1, further comprising, by mass%, one or more of

Cu: 0.1 to 3.0%,
V: 0.03 to 0.5%,
Ti: 0.001 to 0.3%,
Nb: 0.001 to 0.3%,
B: 0.0001 to 0.0050%, and
Ca: 0.001 to 0.010%.

3. The stainless steel sheet for exhaust system part use excellent in intermittent oxidation characteristic according to claim 1 or 2, further comprising, by mass%, one or more of

W: 0.01 to 3.00%,
Zr: 0.05 to 0.30%,
Sn: 0.01 to 0.10%,
Co: 0.01 to 0.30%, and
Mg: 0.0002% to 0.010%.

4. An exhaust system part having a welded structure using a stainless steel sheet according to any one of claims 1 to 3 as a base material and having a gradient of change of sheet thickness at a weld zone of 15 degrees or less.

FIG. 1

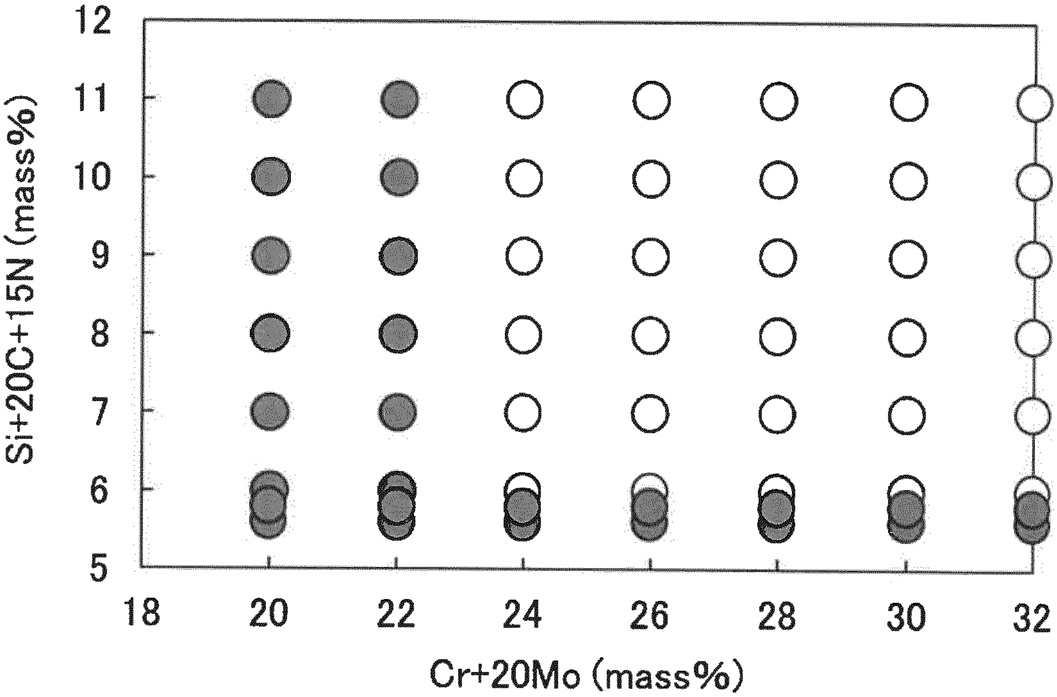
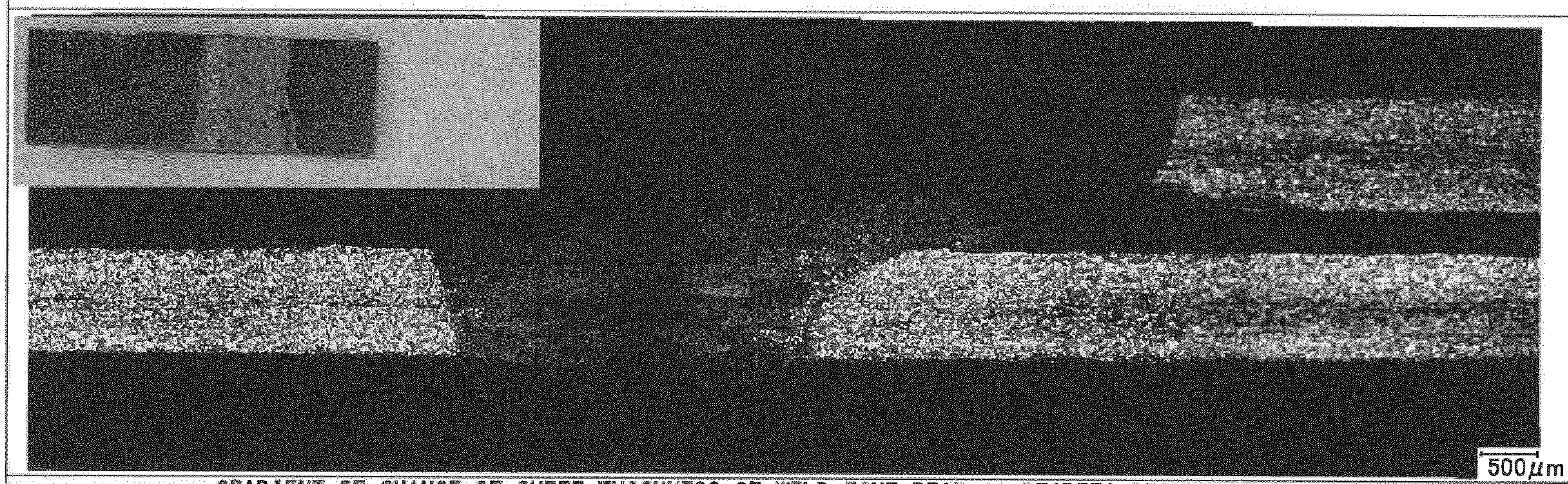
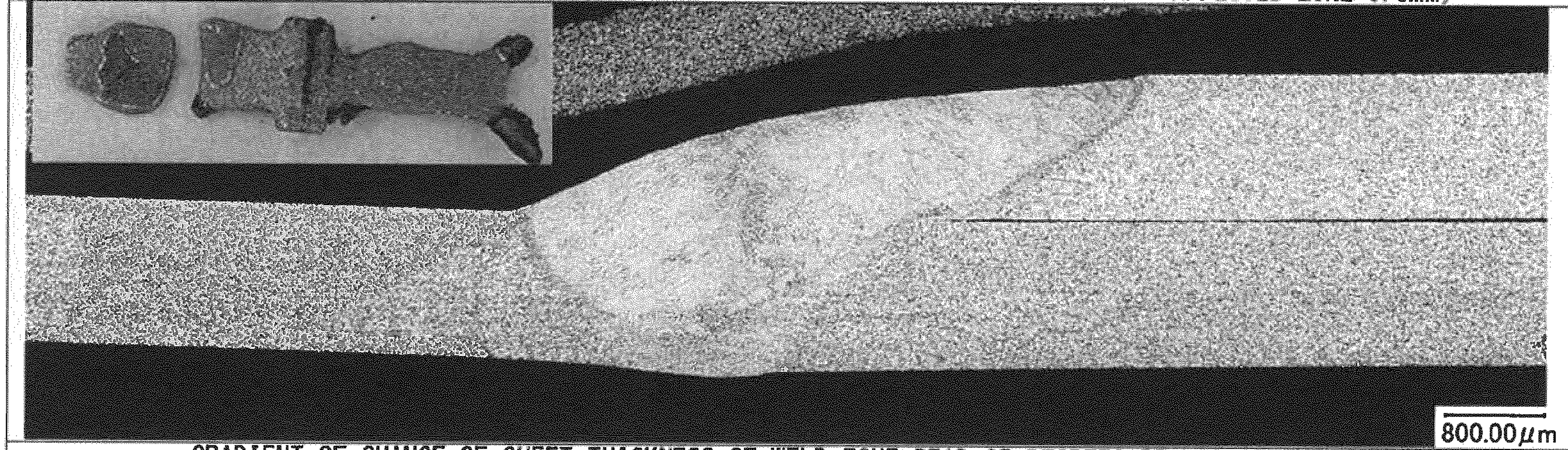


FIG. 2

CROSS-SECTIONAL SHAPE OF WELD ZONE

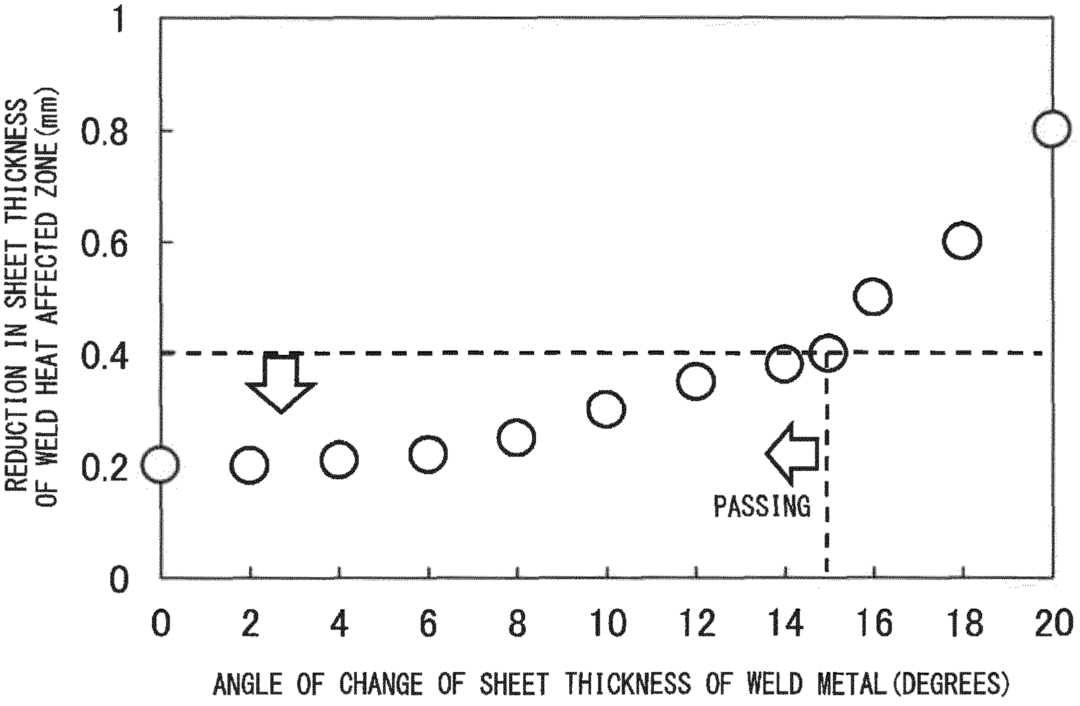


GRADIENT OF CHANGE OF SHEET THICKNESS OF WELD ZONE BEAD:11 DEGREES, RESULT OF EVALUATION OF OXIDATION RESISTANCE:PASSING (REDUCTION OF SHEET THICKNESS OF HEAT AFFECTED ZONE:0.3mm)



GRADIENT OF CHANGE OF SHEET THICKNESS OF WELD ZONE BEAD:25 DEGREES, RESULT OF EVALUATION OF OXIDATION RESISTANCE:FAILING (REDUCTION OF SHEET THICKNESS OF HEAT AFFECTED ZONE:1.2mm OR MORE)

FIG. 3


REDUCTION IN SHEET THICKNESS OF WELD HEAT AFFECTED ZONE (mm)
1
0.8
0.6
0.4
0.2
0
PASSING
0
2
4
6
8
10
12
14
16
18
20
ANGLE OF CHANGE OF SHEET THICKNESS OF WELD METAL (DEGREES)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060249

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C22C38/58*(2006.01)i, *F01N13/16*(2010.01)i, *C21D9/46*(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C38/00, C22C38/58, F01N13/16, C21D9/46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2014/157655 A1 (Nippon Steel & Sumikin Stainless Steel Corp.), 02 October 2014 (02.10.2014), paragraphs [0013] to [0031], [0034] to [0037], [0043]; tables 1A, 2A; examples no.1 to 5, 7 to 22 & US 2016/0032434 A1 paragraphs [0020] to [0041], [0044] to [0047], [0049]; tables 1A, 2A; examples no.1 to 5, 7 to 22 & EP 2980244 A1 & CN 105051233 A & KR 10-2015-0126053 A & MX 2015013607 A	1-3 4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 27 June 2016 (27.06.16)	Date of mailing of the international search report 05 July 2016 (05.07.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060249

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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